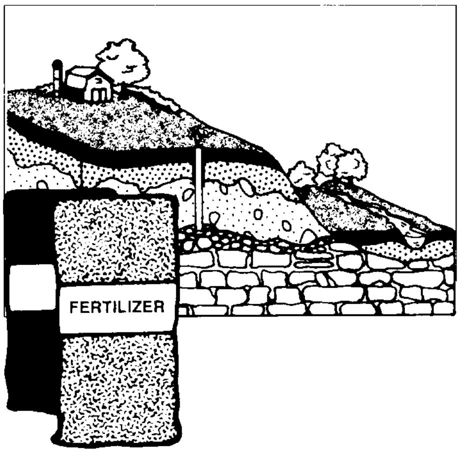


SoilFacts

Nitrogen Management and Water Quality

Whatever its source, nitrogen (N) is essential for achieving optimum yields of grain, forage, and other crops. The same is true of phosphorus (P) and other nutrients. Applying too much nitrogen or phosphorus to cropland, however, can have adverse effects on the environment. Achieving optimum yields without applying excessive nutrients should therefore be a goal of all farmers. Excess nitrogen and phosphorus in surface waters and nitrogen in groundwater cause eutrophication (excess algae growth) in surface waters and health problems in humans and livestock as a result of high intake of nitrogen in its nitrate form.

Effect of Nitrogen on Water Quality

Eutrophication is the slow, natural nutrient enrichment of streams and lakes and is responsible for the "aging" of ponds, lakes, and reservoirs. Excessive amounts of nutrients, especially nitrogen and phosphorus, speed up the eutrophication process. As algae grow and then decompose they deplete the dissolved oxygen in the water. This condition usually results in fish kills, offensive odors, unsightliness, and reduced attractiveness of the water for recreation and other public uses. These poor conditions have been observed in eastern North Carolina in the Neuse, Chowan, and Pamlico river systems. However, this condition occurs only when *excessive* nutrients are present; a certain amount of nitrogen and phosphorus is essential for any life to exist in water.

Excessive nitrate (NO_3) in drinking water can cause human and animal health problems, particularly for small babies. The United States Public Health Service has established a specific standard of 10 milligrams of nitrate nitrogen per liter as the maximum concentration safe for human consumption. Problems in adults that drink water with excessive nitrate are essentially nonexistent and are rare in infants. The principal sources of nitrate and nitrite (NO_2) for adults are vegetables and cured meats, which supply more than 95 percent of the total nitrate in typical diets. Less than 1 percent is from drinking water if it comes from a low-nitrate source, as is usually the case.

Nitrate toxicity does occur in livestock, and the nitrate concentrations that produce toxicity are much higher than those for humans. Nitrate poisoning in livestock depends more on nitrate in feed than in water. Nitrate-contaminated water is usually a problem only when it adds to high nitrate concentrations already present in some feeds.

Fate of Nitrogen in the Environment

The long-term fate of land-applied nitrogen is the same whether it comes from field-applied fertilizer, legume residues, animal, industrial, or municipal wastes, or other sources. The possible outcomes of this applied nitrogen are listed on the following pages.

Nitrogen Remaining in the Soil

The total nitrogen in cultivated soils remains relatively constant over a period of years. Most of the nitrogen is present in organic matter, which varies among soils and among cropping systems on the same soil but is relatively constant for a particular soil on which a given crop rotation is used. Thus, regardless of how much nitrogen from fertilizers, legumes, or animal waste is used on a particular soil, nitrogen does not normally accumulate in the soil. Nitrogen may carry over from one crop to another, but the nitrogen content of a selected cultivated soil does not increase greatly over a period of years. Thus, most of the nitrogen is lost from the soil in one way or another. Regardless of whether nitrogen is in the organic or inorganic form when applied to crops on North Carolina soils, it undergoes transformation to yield nitrate as an end product.

Recovery of Nitrogen in Harvested Crop

The amount of nitrogen harvested by crop plants is less than most people assume; for example, recovery of only 50 percent of the applied nitrogen is a good average. However, the recovery rate varies for different crops and soils. Research in North Carolina has shown that 90 percent or more of the nitrogen applied to sod crops (such as bluegrass or coastal bermudagrass) is commonly recovered. Flue-cured tobacco recovers 70 to 80 percent in seasons of average rainfall. The recovery of nitrogen applied to corn for grain largely depends on the amount applied and the yield obtained. Approximately 0.8 pound of nitrogen is harvested with each bushel of corn. Farmers who apply 150 pounds of nitrogen per acre and harvest 100 bushels per acre recover approximately 53 percent of the applied nitrogen. However, if farmers harvested only 50 bushels per acre from the same nitrogen application, they would have recovered only 27 percent of the applied nitrogen. The percentage of recovery would be increased considerably if the corn were harvested for silage.

The above examples suggest that in most seasons an average of 30 to 50 percent of applied nitrogen may not be used by the crops. This nitrogen may be lost by leaching or runoff and represents a potential source of pollution.

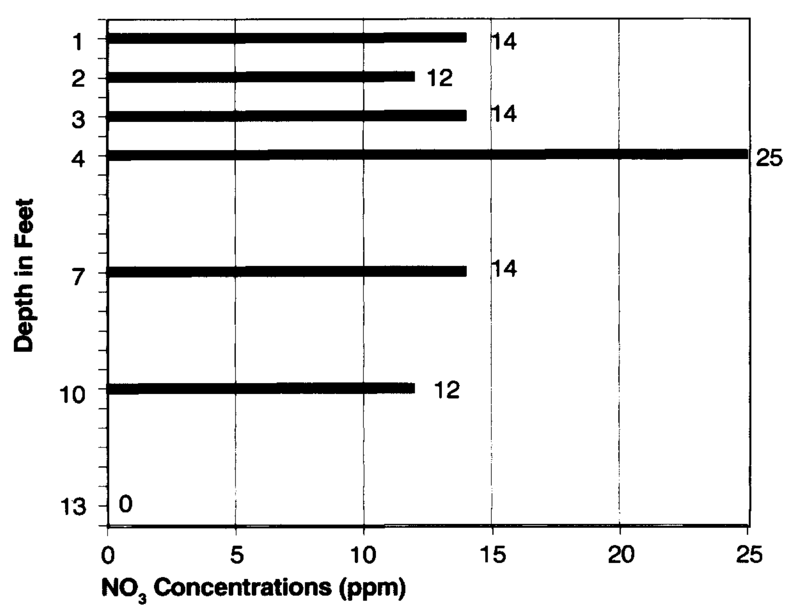
Fertilizer Nitrogen Lost to the Air as Gas

North Carolina State University soil scientists have documented that some of the nitrogen that moves below the plant root zone is lost to the atmosphere through a process called *denitrification*. This process is the breakdown of nitrate to simple nitrogen (N_2) and oxygen (O_2) gases that return to the atmosphere. Loss of nitrogen as a gas by this process is not extensive in well-aerated, cultivated soils. Nitrogen applications to high-water-table soils of the lower coastal plain that are poorly drained and high in organic matter are the least likely to contribute to contamination of groundwater by nitrate. The organic matter in the shallow groundwater provides energy for microorganisms that promote denitrification and thus much of the nitrogen is lost in the gaseous form rather than as nitrate.

Studies have shown that nitrate levels are not alarming even in moderately to well-drained soils with low organic matter where little denitrification occurs (Figure 1).

The lack of nitrate below 13 feet may also be explained by the presence of an almost impermeable horizon (soil layer) between the 9- and 12-foot depths. These confining beds or layers are very common in the upper and middle coastal plain. Water reaching these layers flows laterally to a lower elevation where it frequently enters a stream through

Figure 1. Groundwater NO_3 concentration of a Goldsboro soil near Kinston, N.C., cropped to corn.



a seep. Furthermore, in many places throughout the coastal plain (and other regions of the state), much of the nitrate flowing laterally to an outlet is either used by plants in these wet natural areas or is lost through denitrification. The same processes have been observed in Georgia and Maryland. Thus, nature has a very effective way of removing much of the nitrate before it can cause problems.

A limited number of samples collected in piedmont soils have shown low nitrate concentration levels within the soil profiles (Figures 2 and 3).

Fertilizer Nitrogen Removed from the Soil in Surface and Subsurface Drainage

Nitrogen from fertilizers may enter streams through surface or subsurface drainage (leaching). Considerable loss of nitrogen may occur if heavy rains immediately follow a surface application of fertilizer on a moist soil surface, particularly if there is considerable slope. However, fertilizer nitrogen in surface runoff will be low if the fertilizer is mixed with the soil. The loss of organic nitrogen (contained in crop residues, animal waste, or soil material) could be considerable if intense rainfall results in substantial soil and debris movement.

Because it has a high solubility, nitrate nitrogen normally moves readily into the soil with the initial rainfall. Thus, if fertilizer nitrogen is a source of pollution, it is usually from leaching or subsurface drainage.

Leaching has been studied within and slightly below the root zone; however, the study of nitrate movement from the point of application to the groundwater has been very limited. In some sandy North Carolina soils, considerable nitrate has been observed 2 feet below the point of application after only 3 inches of percolated water. On similar soils in Georgia, considerable nitrate

Figure 2. Groundwater NO_3 concentration in an old cultivated Vance soil profile at the Oxford, N.C., Research Station.

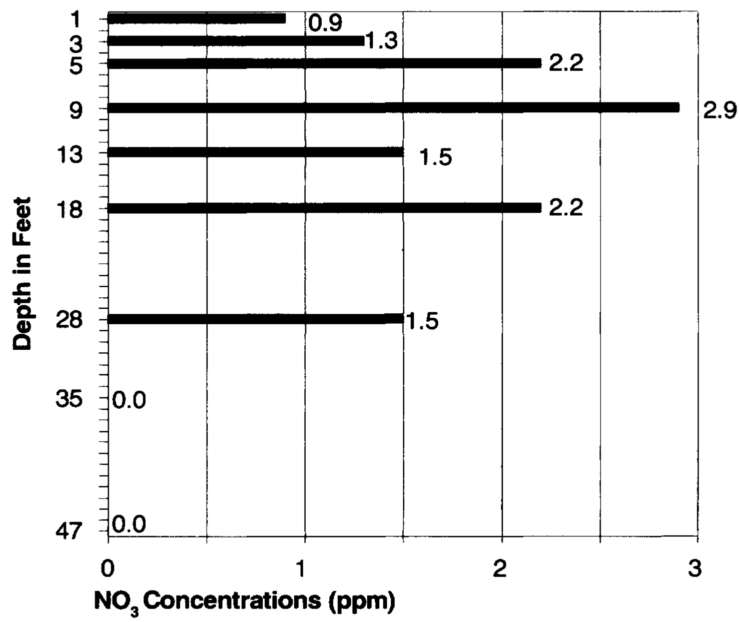
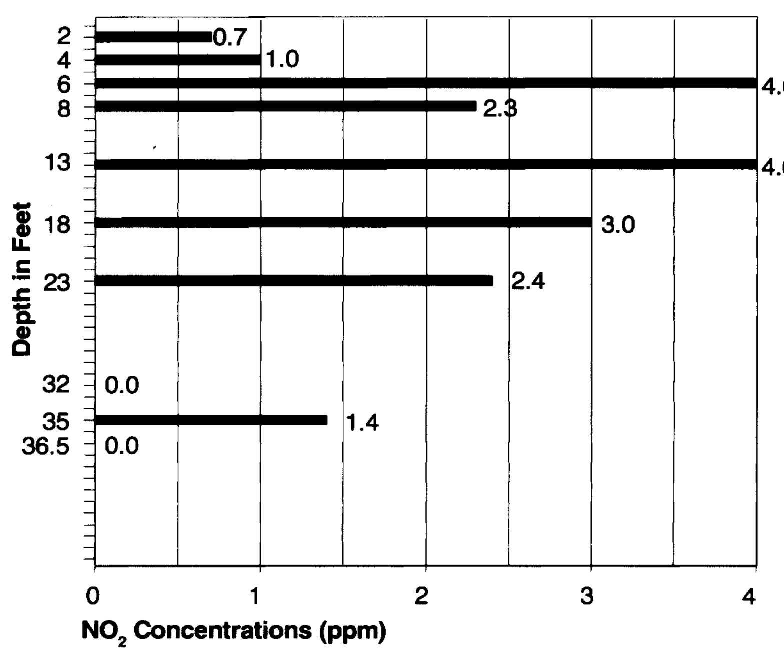


Figure 3. Groundwater NO_3 concentration in an old cultivated Appling soil profile at the Upper Piedmont Research Station, Reidsville, N.C.



leached below 3 feet in 50 weeks with 42 inches of rainfall. Although evidence is not available to state precisely how much fertilizer nitrogen gets into the water via leaching, the foregoing information can be used to make some estimates. Because nitrogen does not accumulate in the soil and 30 to 50 percent of the applied fertilizer is not harvested with the crop, this nitrogen must be escaping into the air or water.

In North Carolina, evapotranspiration (water that evaporates from leaves and soil surfaces) exceeds rainfall only during the summer months (April to August). The average annual rainfall in North Carolina is approximately 49 inches and the average evapotranspiration is approximately 35 inches. The excess 14 inches of water either runs off or percolates through the soil; in either case it ultimately enters streams, groundwater, or both. This water can become contaminated with excessive soluble nutrients from various sources.

In 1985 and 1986, a total of 245,751 tons of fertilizer nitrogen were used in North Carolina. If all this nitrogen were put directly into the 14 inches of drainage water over the state's total area, the average nitrogen concentration would be only 4.6 parts per million. In previous sections it was shown that on the average at least 50 percent of the applied nitrogen is used by the crop. Soil scientists propose a method that shows an average nitrogen concentration in waters resulting from the use of fertilizer (Table 4). From these data it appears that fertilizer nitrogen does not contribute greatly to the nitrogen content of streams.

Table 4. Potential Average Nitrogen Concentration[1]

Applied N Used By Crop (percent)	Potential Avg. N Concentration In Drainage Water (ppm)
0	4.6
25	3.4
50	2.3
75	1.2
90	0.5

[1]In drainage waters based on fertilizer usage in N.C. in 1985 and 1986 assuming that all nitrogen not used in the crop gets into the water.

Management of Nitrogen to Uphold Water Quality

Because nitrate in groundwater and surface water is a potential health hazard and contributes to current eutrophication problems, fertilizer nitrogen must be used prudently on crops. Listed below are some techniques for guarding against the possibility of unused nitrate contaminating surface water and groundwater supplies.

- ❑ Apply two-thirds to three-fourths of the planned fertilizer nitrogen just before the crop enters a period of rapid growth. Proper timing ensures maximum daily nitrogen uptake and minimizes the likelihood of unused nitrogen leaching below the plant roots.
- ❑ Apply a reasonable amount of nitrogen to your crop. When grain and forage yields are low, less nitrogen will be removed with the grain, silage, or hay crop or by grazing. Because a soil test is not a reliable means of predicting nitrogen response, consider analyzing plant samples collected early in a period of rapid growth. The need for additional nitrogen can be determined and applied before the crop matures.
- ❑ If your crop will follow peanuts, soybeans, or forage legumes (clover or alfalfa) of average or greater yield, reduce the amount of nitrogen you apply. Soybeans and peanuts may provide 20 to 40 pounds of carryover nitrogen per acre. A "strong" alfalfa stand may provide 80 to 100 pounds of nitrogen per acre for the next crop.
- ❑ Be sure to analyze animal, municipal, and industrial wastes for nitrogen content when applied to cropland. Guard against "dumping," as this practice may contaminate water with excess nitrate.
- ❑ Throughout the sandy soil surfaces of the coastal plain, do not apply nitrogen in the fall for spring-planted crops. Piedmont fields may receive some nitrogen (up to one-half of crop needs) for spring-planted crops.

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